The Winds of Change

The story of wind generation in the Yukon

Yukon Development Corporation

YUKON ENERGY

Environmentally friendly wind

- World wind energy potential has been estimated at 10 million megawatts (10,000 GW).
- North American wind energy potential is 2,300 GW; current installed capacity is 2.7 GW.
- Canada could service 10% or more of electrical needs from wind. Installed capacity is now about 140 MW, with applications submitted in Alberta for a further 200 MW capacity in wind farms near Pincher Creek.
- Operating costs are generally lower for wind farms than diesel plants; there are no fuel costs.
- Wind turbines can be added to wind farms one by one, increasing capacity when needed.

"Wind is totally benign and it's totally renewable. You just wait until the wind blows. You're not burning any fossil fuels and creating carbon dioxide. You're not damming up a river."

Jack Cable, former president, Yukon Energy Corporation

What's needed for economic utility scale wind generation?

- Consistent wind speeds greater than six metres/second.
- Access to electric power grid.
- Large capital investment.
- Power markets that can adjust to wind supply variations.
- Ability to produce power at costs equivalent to competing technology (diesel).

1) Pincher Creek, Alberta: vertical axis wind turbines. 2-3) Cowley Ridge, Alberta. 4) Ebeltoft, Denmark: 16 turbines service 600 homes; mid-1980s installment.

Yukon photographs: (top) At Silver City, Jack Hayden was using wind for both pumping water and generating electricity in the summer of 1942. (Yukon Archives, John Baxton Coll.). (middle, l to r) Broken wind monitoring tower on Flat Mountain, 1991. Hydro-Tech instruments on Haeckel Hill, winter 1994. Second tower on Haeckel Hill, with NRC anemometer, summer 1993. (bottom) Bonus 150 kW and Vestas 660 (right), on Haeckel Hill, Whitehorse. Airport is on flat area to the far right, down in the valley.

YUKON POWER GENERATION

Wind turbine generation is now an established part of the Yukon's electrical power supply system. However, 12 years ago, wind was almost written off as a viable energy option. This pamphlet explains how the Yukon's electricity is generated and tells how wind came to be a part of it.

Hydro and diesel

Because of its isolation, the Yukon is not a part of the North American power grid. And within the territory, only half a dozen communities are serviced by the Yukon's own power grid, the Whitehorse/Aishihik/Faro (WAF) system. This grid takes its name from the two hydro plants that supply most of the power, Whitehorse Rapids and Aishihik Lake, and from Faro, the site of a massive lead-zinc mine, once the Yukon's largest industrial power customer. The WAF grid was originally built around the needs of the Faro mine, which is no longer operating.

While most of the grid's needs can usually be met by hydro, there are times during the winter when the system has had to use diesel generation to meet customers' needs.

Also, diesel electric generation supplies all off-grid communities except for those in the Mayo area which are served by a 5 MW hydro plant.

Wind as an alternative

During the 1980s, two Yukon government initiatives — the Yukon Conservation Strategy and the Yukon Economic Strategy — looked at how energy would be part of the Yukon's future growth. These strategies suggested that power generation using local renewable energy sources such as wind, could replace imported diesel. This would also provide opportunities to enhance self-sufficiency, reduce economic leakage, and create opportunities to diversify the economy.

In the 1990s, the international community began to recognize climate change to be a serious issue. Greenhouse gas emissions (mainly carbon dioxide) from diesel electric generation became a factor in discussions of energy use. Wind-generated power was identified as a way to reduce these greenhouse gas emissions.

Also in the 1990s, when the Faro mine was operating, power demands on the WAF grid were greater than its hydro generation capacity. If wind could produce power during the winter months, it was expected that it could replace the diesel burned during peak demand periods.

Early wind work

Wind has been put to work in the Yukon since the middle of the last century. A wind generator supplied power for lights at the Old Crow store in the 1950s and isolated homesteads used wind turbines to charge battery banks for home electrical systems.

But no one looked at the commercial potential of Yukon wind until 1982. In that year, the National Research Council erected a tower and monitoring instruments at Burwash Landing on Kluane Lake, an area known for its winds. Results were not good and the effort was abandoned.

In the late 1980s, with the Yukon Conservation Strategy in mind, the Yukon government reactivated the NRC monitoring equipment and also reviewed wind data collected at the Whitehorse airport weather station. The findings from both sites indicated that available wind energy would not support commercial generation.

That could have been the end of the story.

(below) Whitehorse Rapids dam. (above) One of the seven diesel generators in Whitehorse.

THE YUKON'S WIND STORY

The two wind turbines on Haeckel Hill would not be feeding power to the Whitehorse/Aishihik/Faro grid without the efforts of two Yukon residents: Jack Cable, current Commissioner of the Yukon, and his friend and fellow engineer, Dr. Doug Craig. Both are quick to say that their efforts depended on the support of the community at large and the willingness of Yukon Energy Corporation to look at alternatives to hydro and diesel.

Wind pioneers

A chemical engineer and lawyer, Jack Cable was first alerted to environmental issues in the early 1960s by Rachel Carson's book, *Silent Spring,* and as a result of a chemical spill at the company he worked for in southern Ontario. He carried an environmental ethic with him when he later moved to the Yukon. As a director of the Northern Canada Power Commission in the early 1980s, Cable learned of wind research in the United States and Canada, and was impressed by Boeing Aircraft's 2.5 MW horizontal axis wind turbine in Goldendale, Washington and a vertical axis turbine in Oregon. His interest in wind led to discussions with a Whitehorse friend, Doug Craig.

Doug Craig is a geological engineer. He obtained his doctorate in geology and a sensitivity to environmental issues from the University of Wisconsin, which offered some of the first courses on ecology and conservation. Craig came to the Yukon as regional geologist for Indian and Northern Affairs Canada. In 1980, after hiking many windy Yukon mountain ridges, he wondered about wind energy potential and wrote to the C.D. Howe Institute to see if there were weather instruments available that could measure wind velocities in cold weather. He was assured that there were anemometers (wind speed recorders) that worked to -20° Celsius. However, this was hardly good enough for the Yukon and so the idea of wind power slipped to the back of his mind.

Jack Cable supporting the Bonus!

In the mid-1980s, both Cable and Craig served on the public working group that developed the Yukon Conservation Strategy and endorsed its commitment to making the Yukon more energy self-sufficient.

Getting serious

By 1989, Craig and Cable were again thinking about wind. Cable suggested that it might be worth investigating the Yukon's wind potential and Craig reviewed the literature. His early research wasn't promising. Whitehorse weather station records — from readings taken at the airport — showed wind levels below those that could produce usable power. National Research Council (NRC) information from the meteorological instruments installed at Burwash Landing on Kluane Lake was equally bleak. The wind regime there had been monitored by NRC from 1982 to 1984 and by the Yukon government in 1987 and 1988, with poor results.

Craig later learned that there had been real problems with this data because the instruments had iced

Craig family and crew on Haeckel Hill preparing tubular tower for lift, summer 1992.

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First wind monitoring tower on Haeckel Hill. 1) David Craig assembling the NRC tower. 2) Doug Craig on the ladder above the histogram recorder. 3) Gin pole used to add the third section.

up during the winter and recorded no wind at all for extended periods. When he learned that the weather office in Whitehorse also had weather balloon-based wind velocity information, he asked Environment Canada staff to pull out readings for the higher elevations. Through all of 1989 and the spring of 1990, Craig made bimonthly pilgrimages to the weather office to collect this data. The results showed good wind velocities at 1,500 metres, and anyone could see there were plenty of mountains of that height, or taller, around Whitehorse.

Both Craig and Cable thought these findings were worth following up. They met with John Maissan, Director, Technical Services at Yukon Energy Corporation (YEC), to tell him about their research. Maissan was intrigued by the findings. While previously employed with the Yukon government's Mines and Energy Branch, he had read the same research information as Craig had and had pretty well written off wind as a viable energy alternative.

After the meeting, Cable suggested to Craig that it was time to get serious. "We can't just be two boffins. We have to be a corporate entity." So they founded the Boreal Alternate Energy Centre.

Monitoring the wind

In 1990, Boreal published its first report on Whitehorse wind generating potential, based on weather balloon data compiled and analyzed by Dr. Craig. The report was co-authored by Craig and his son, David. Determined to move things forward, Boreal rounded up the two National Research Council wind monitoring instruments that had been sent to the Yukon in 1987. The Yukon Electrical Company Ltd. agreed to transport one unit, along with its 60-foot tower, from Burwash Landing. The other was found under a desk in the Energy Branch of the Yukon Department of Economic Development.

Boreal next approached Yukon Energy Corporation for assistance in erecting the 60-foot NRC tower and monitoring equipment. By agreeing to contribute $1,500 to the effort, YEC began its formal involvement with wind. Subsequent funding for the project was provided by the Canada-Yukon Economic Development Agreement.

While driving up Grey Mountain with the instrument tower, looking for a suitable site, Craig and Cable put a permanent crease on the top of Cable's Suzuki jeep. When they saw bullet holes in signs, and evidence of vandalism at the communications tower shack already there, they had second thoughts. They turned instead to Haeckel Hill. Unlike Grey Mountain, it is aligned perpendicular to Whitehorse's prevailing south winds. There was also road access.

Yukon wind research findings

- **Wind speeds are greater at higher elevations.**
- **Wind energy is usually greater in winter months (when electrical demand is highest) and hydro potential is lowest.**
- **All sites tested in the Whitehorse area — Haeckel Hill, Mount Sumanik and Flat Mountain — have wind speeds greater than the six metres per second considered adequate for wind farming.**

First wind monitoring tower on Haeckel Hill. 1) David Craig assembling the NRC tower. 2) Doug Craig on the ladder above the histogram recorder. 3) Gin pole used to add the third section.

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John Maissan on Old Crow Mountain with the community of Old Crow on the river bank far below.

and power to the forestry observation tower near the top.

So, in the spring of 1990, Cable and Craig erected the tower and wind measuring instruments at the 1,500-metre level on Haeckel Hill. During the following winter, Craig and his son discovered that the wind monitoring equipment iced-up regularly. Countless winter truck and snowmobile trips were made to remove rime ice accumulations and to collect the recorded data. Despite the icing problems (eventually solved with heated Hydro-Tech instruments) it became clear that Haeckel Hill experienced 10 times more wind energy than the area around the Whitehorse airport. It wasn't long before Cable was asking Craig if there might be locations that would generate even more power than the Haeckel site.

In 1991 and 1992, Craig set up instruments on Mount Sumanik at 1,700 metres and on Flat Mountain at 1,940 metres. They revealed 15% and 30% wind energy increases, respectively, from Haeckel Hill. However, wind and ice proved very hard on the instruments and towers at these locations. The Flat Mountain site, in particular, was very hard to service.

In 1991, Jack Cable was named president of Yukon Energy Corporation and Yukon Development Corporation, bringing with him his interest in wind energy. Before the end of his term, the YEC board had been convinced that wind-generated power should be formally investigated. By the end of 1992, corporation staff were in discussion with a Danish supplier about the purchase of a wind turbine. It was time to find out if a wind turbine could produce reliable power in Yukon conditions and supply wind-generated power to the grid.

A new generation of wind monitoring

The Boreal Alternate Energy Centre's successful wind monitoring work not only encouraged Yukon Energy Corporation's investment in the Yukon's first commercial wind turbine, it also set up a wave of wind monitoring efforts.

Since 1992, YEC has been studying wind conditions at locations around the territory including Whitehorse, Tagish, Haines Junction, Destruction Bay, Dawson City, Old Crow and Faro.

Where power is accessible, heated Hydro-Tech instrumentation can log wind data at elevations where rime icing would shut down conventional anemometers.

At some sites, such as the Dawson East Dome location, lack of a power supply has limited data collection during cold weather and in rime icing conditions.

Yukon Energy Corporation is now developing a monitoring system that

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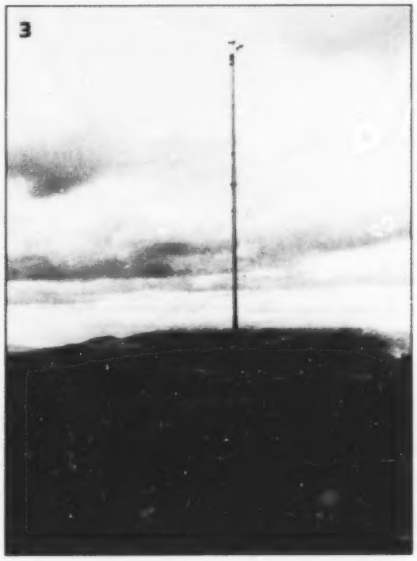
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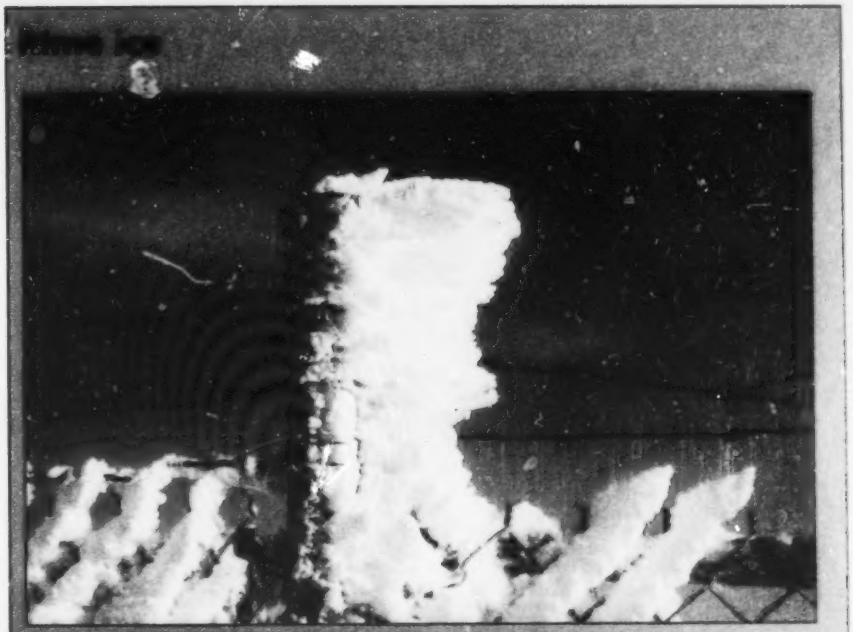
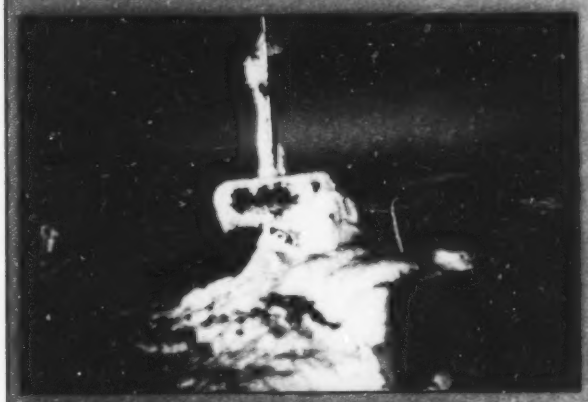
...The Yukon's wind story

will make it possible to log wind information at remote locations. The unit being tested on Mount Sumanik, near Whitehorse, uses a photovoltaic array, a small wind generator and a battery bank to supply power to heat wind-measuring instrumentation.

Various Yukon wind monitoring setups: 1) Haines Junction, 2) Dawson City, 3) Tagish, 4-7) Mount Sumanik.





"Rime icing is a white frost-like build-up that you see on branches and trees around open water and occurs whenever there's a cloud contacting a mountain or ridge.

"Any solid object accumulates ice which 'grows' into the wind. Trees become ice domes, towers become ice posts, power lines grow to six or eight inches in diameter, and chain link fences become solid walls."

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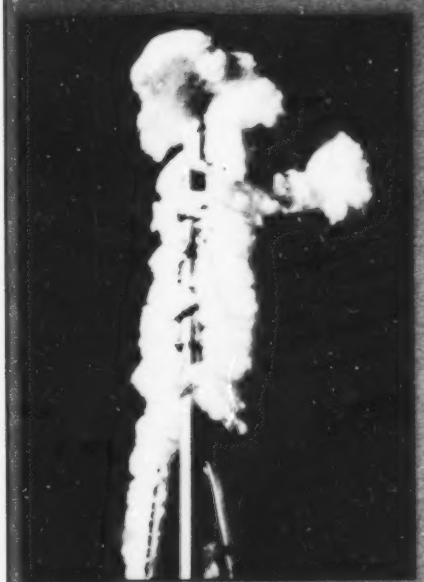

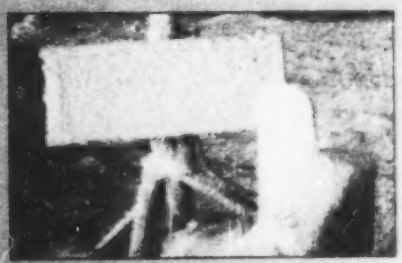

Rime ice on a chain-link fence on Haechel Hill (note how rime ice grows into the wind), and at Old Crow, on the monitoring instruments and on the photovoltaic array.

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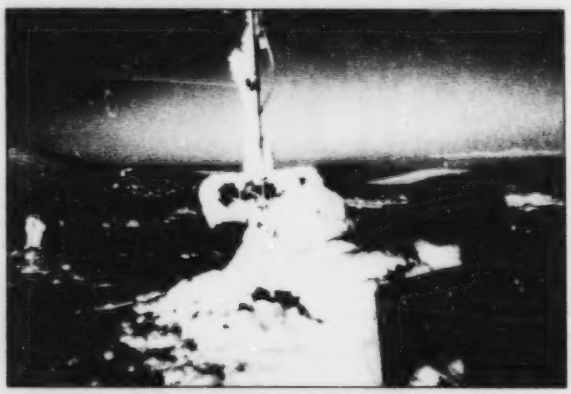
Rime ice



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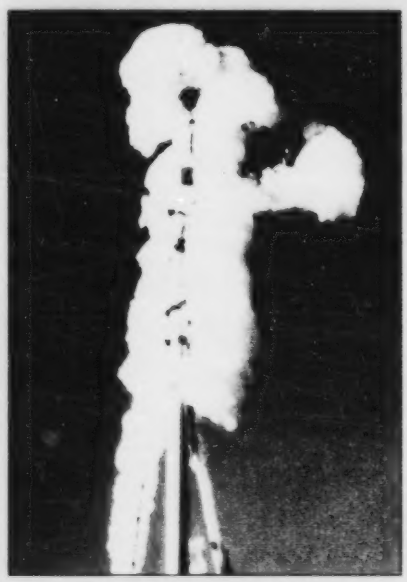


Rime ice on a chain-link fence on Haeckel Hill (note how rime ice grows into the wind) and at Old Crow, on the monitoring instruments and on the photovoltaic array.

BONUS 150 kW MARK III

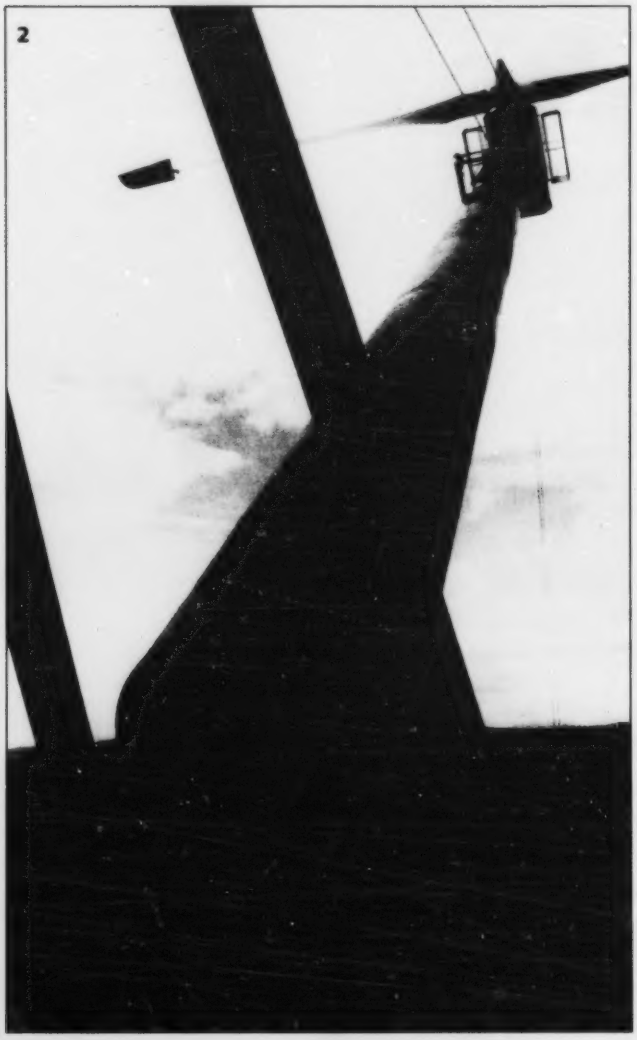
In December 1992, Yukon Energy Corporation placed an order with Bonus Energy A/S of Denmark, a large, proven European manufacturer, for the Yukon's first commercial wind turbine. YEC chose a wind turbine at the small end of the commercial scale to minimize the capital outlay required. It was erected on Haeckel Hill in July, 1993 at a cost of $1,000,000, including $200,000 for upgrades to the access road.

YEC's goal for the Bonus was to see if it would be possible to use wind to generate electrical power in the Yukon's climatic conditions.

Specifications

- 150 kW capacity, 160 kW peak capacity
- 30-metre hub height (tubular tower)
- three-blade upwind design (fiberglass, two section blades)
- 23.8-metre diameter blade circle
- power output aerodynamic-stall regulated
- operates in wind speeds from 4 m/s (14 km/h) to 25 m/s (90 km/h)
- two speeds (30 and 40 rpm), two generators (asynchronous)
- normal operating range down to -30°C in the turbine housing

(below) Special-order tilt up tower for the Bonus 150. (right) Bonus 150 as it looks today.



Installing the Bonus 150. The crane lifted the tower from the cradle (1) high enough so that the hydraulic winch, secured by a Cat (2,3) could apply leverage through the gin poles to pull the tower vertical. The winch anchor foundation cracked as the tower was being lifted. It then had to be encased with steel plate as reinforcement. It took six hours to winch the tower upright.

Birds

Bird strikes have been a concern at southern wind farms. However, five years of bird studies at the Haeckel Hill site have given the wind turbine a clean bill of health. Migration routes for waterfowl are in the valley below the turbine site.

Special Yukon features for the Bonus 150

From the experience with the wind monitoring equipment, Yukon Energy Corporation knew that there were sure to be specific "northern" problems with the Bonus turbine as it would come shipped from the factory. Low winter operating temperatures, rime icing and the lack of a large industrial crane all posed potential problems. Therefore, Bonus, a manufacturer with northern experience, worked with YEC to make technical modifications to suit Yukon conditions before it even shipped the turbine. These included:

- low-temperature-tolerant steels
- synthetic lubricants
- six-inch heating strips for the blade leading edges
- heating systems in the gearbox, generator and electronic cabinets
- heated bearings for the wind vane and anemometer (wind velocity measuring device)
- hinged 30-metre tower capable of installation without a large crane

Installing the Bonus 150. The crane lifted the tower from the cradle (1) high enough so that the hydraulic winch, secured to a Cat (2,3) could apply leverage through the guy poles to pull the tower vertical. The winch anchor foundation cracked as the tower was being lifted. It then had to be encased with steel plate as reinforcement. It took six hours to winch the tower upright.

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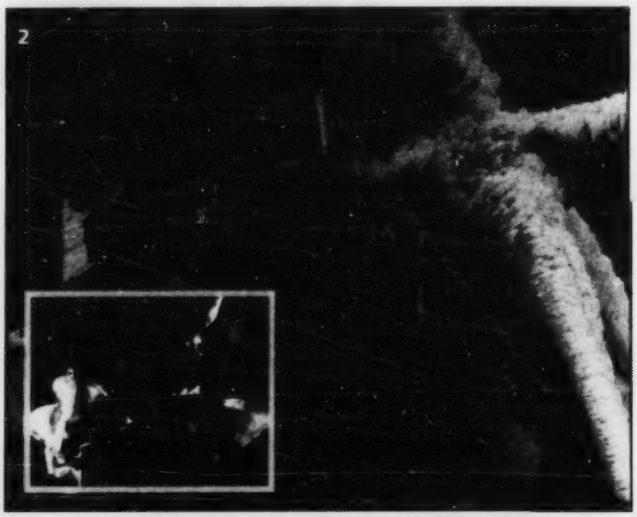
Operational challenges

Even with the special modifications that had been made to the Bonus before it was installed, particular problems developed that hadn't been anticipated.

- Blade icing behind the heaters caused efficiency losses.
- Icing on overhead power lines that ran from the turbine down the hill to the electrical grid caused about five outages per month.
- The heated-bearing anemometer iced up.
- The two-section blades meant that the blade tip heaters often didn't work, leading to tip icing and reduced efficiency.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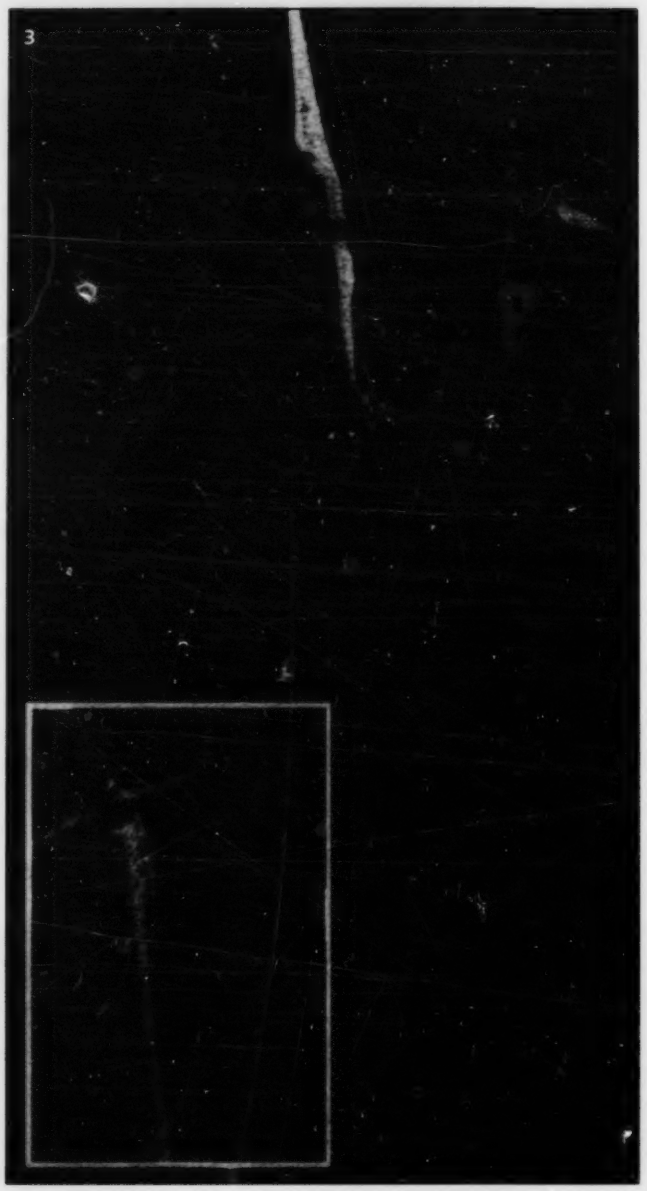
Yukon-developed solutions

To deal with these problems, Yukon Energy Corporation made modifications to the turbine after it was erected on Haeckel Hill.

- Wider heating strips were installed to extend the ice-free blade area and increase efficiency.
- The power line was replaced with buried cable, thus eliminating the power line outages.
- Installation of a fully heated anemometer and wind vane eliminated rime icing problems with them.
- A black-coloured fluorourethane (StaClean) coating was applied to the blades to encourage ice shedding.

The blade joint problem has not been solved, and the Bonus runs with reduced efficiency in rime icing conditions when ice builds up on the blade tips.

With the modifications developed and installed in the Yukon, the efficiency of the unit has improved and it is currently operating at a capacity factor of about 21%.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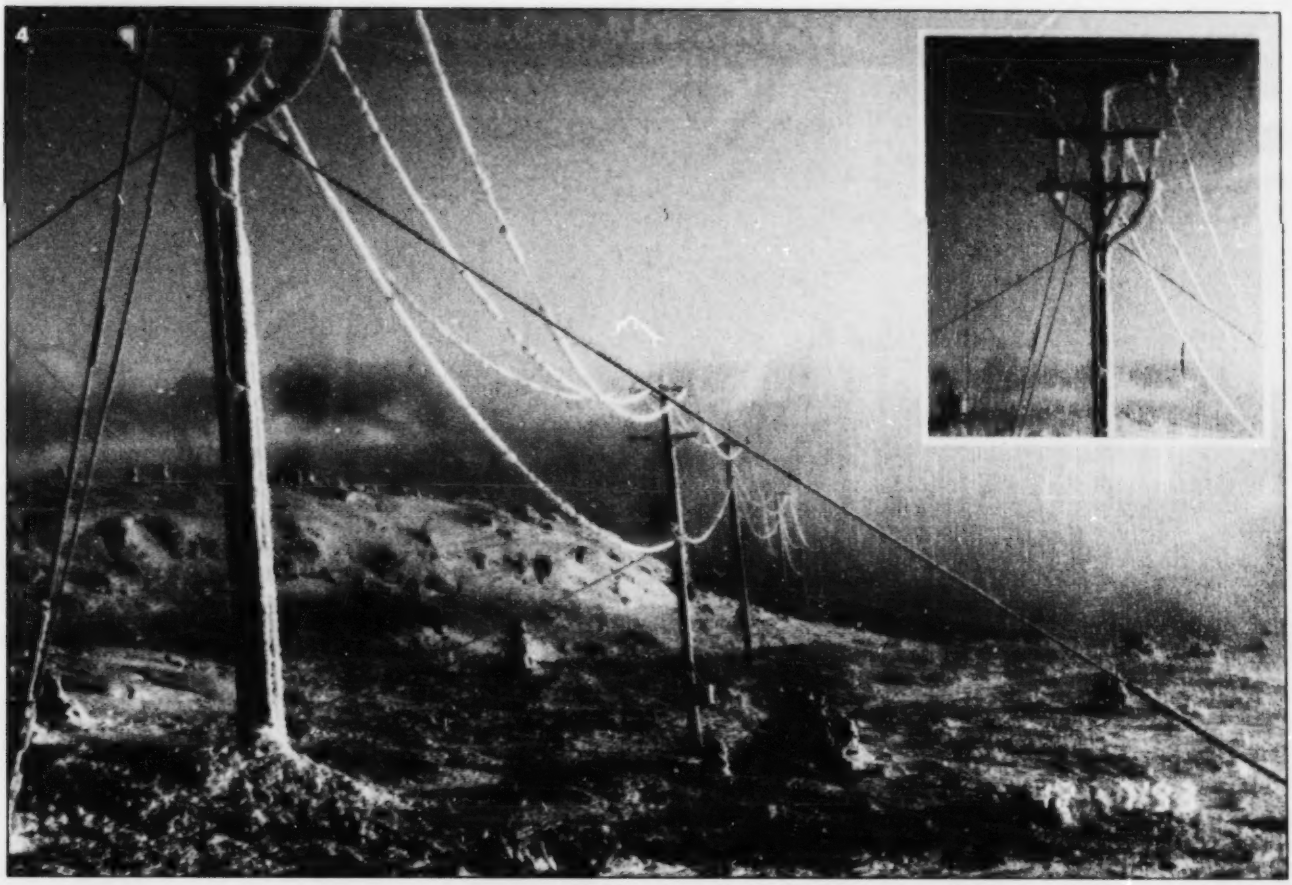
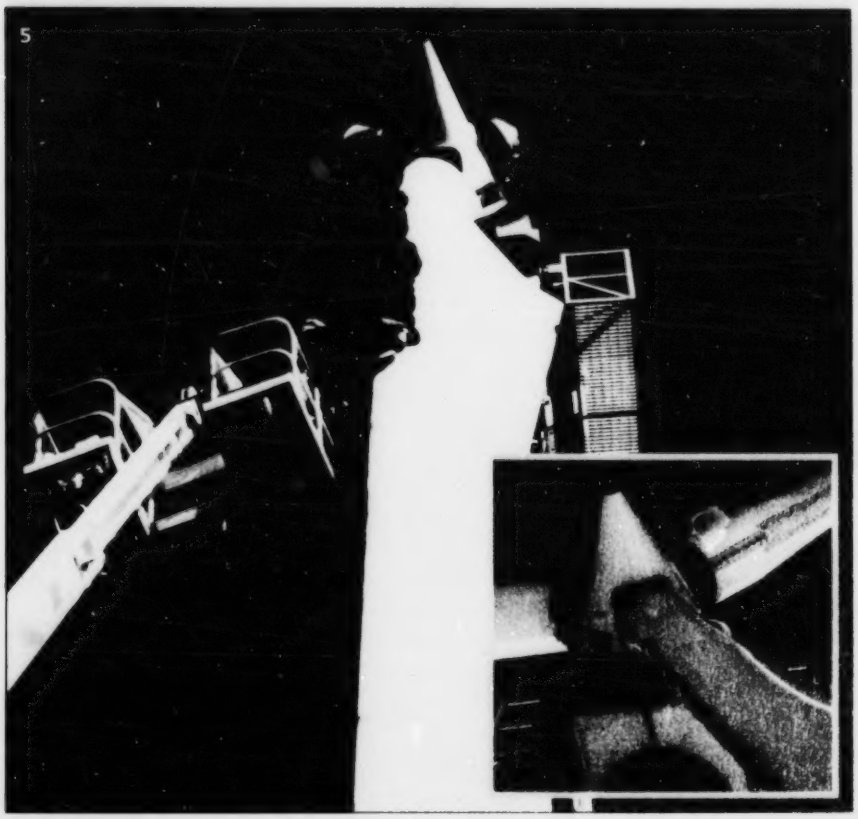
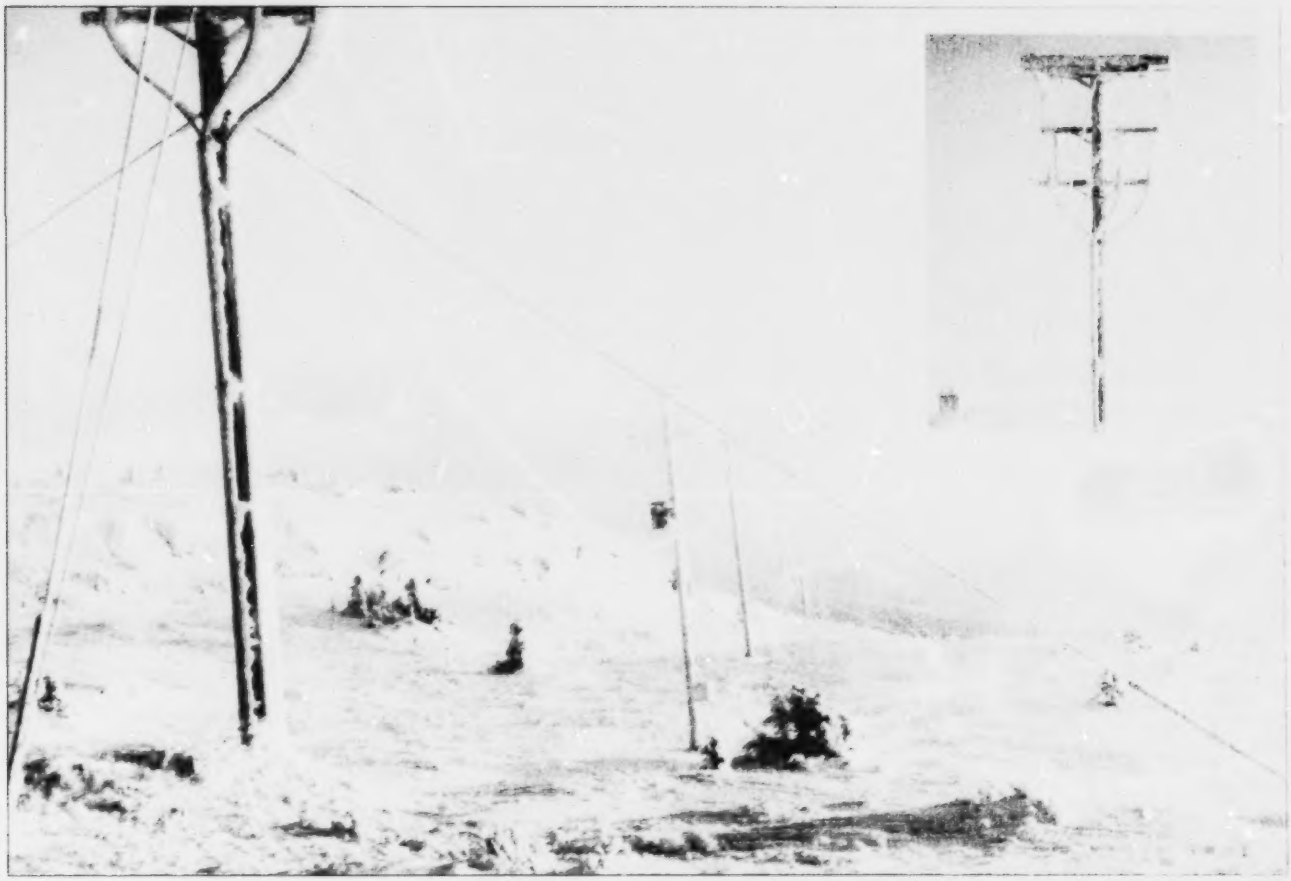


Icing on the Bonus wind turbine: 1) blade tips, 2) instrumentation, 3) blades. 4) Power lines sagging under the weight of ice. 5) Applying StaClean coating to the turbine blade. Inset photo shows heating strips.





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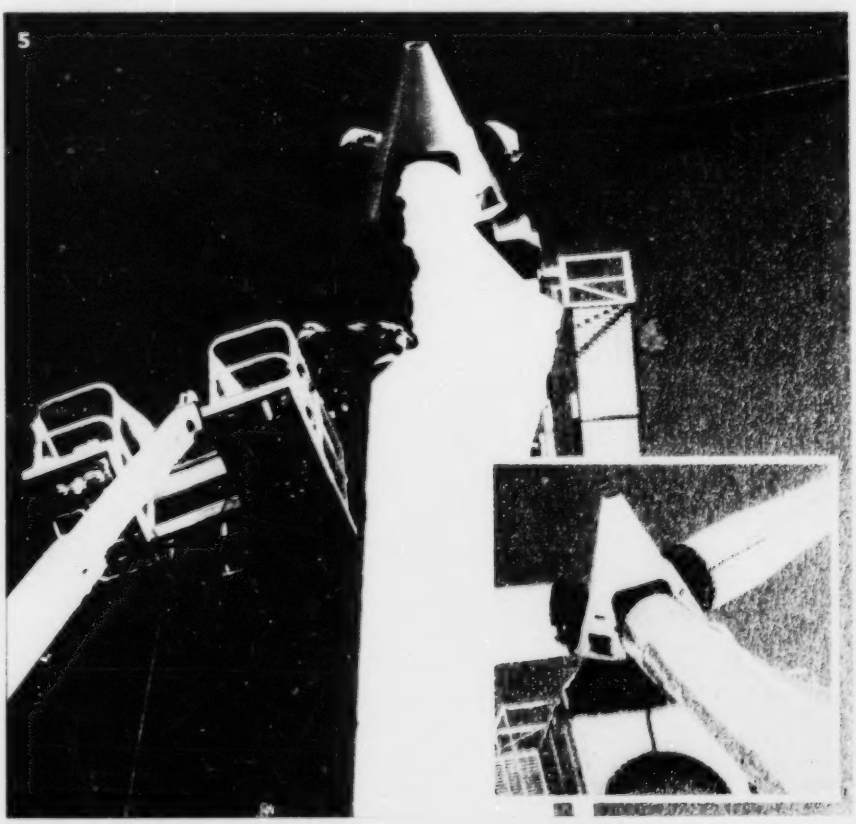


On the leading edge

"The systems to maximize the actual power output in our adverse conditions — lower temperatures and rime icing — were very much leading edge and still are in terms of what's happening throughout the world.

"Just by doing what's good for us we've developed expertise, in a niche market, that is suitable for use anywhere in northern North America, Scandinavia and Siberia."

John Maissan,
Director, Technical Services,
Yukon Energy Corporation

VESTAS V47-660 kW

In the fall of 2000, seven years after the installation of the Bonus 150 wind turbine on Haeckel Hill, a second wind generator was erected. The Vestas V47-660 kW was made by Vestas Wind Systems A/S of Denmark and Vestas-American Wind Technology Inc. USA. The total cost for this installation was $2,000,000.

The Bonus had established the technical feasibility of wind generation in Yukon conditions. The Vestas is intended to test the commercial viability of wind generation, that is, the ability to use wind to generate electrical power at costs below those of diesel generation in Yukon conditions.

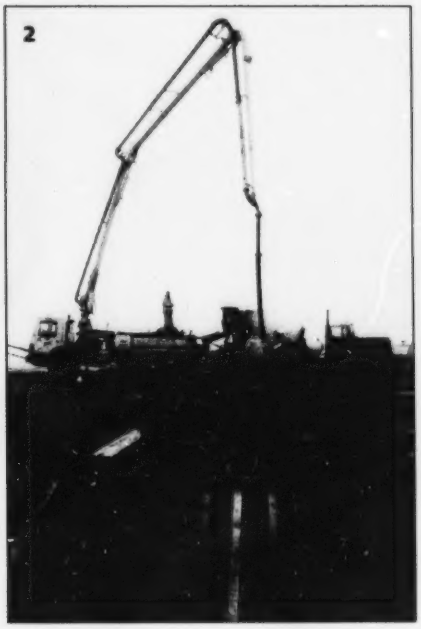
Based on experience with the Bonus 150 kW, the Vestas V47-660 kW was chosen because of features that should make it easier to operate and maintain here in the north. These include a tubular tower that allows indoor climbing and maintenance while sheltered from the weather, and one-piece, variable-pitch wind blades to maximize power production.

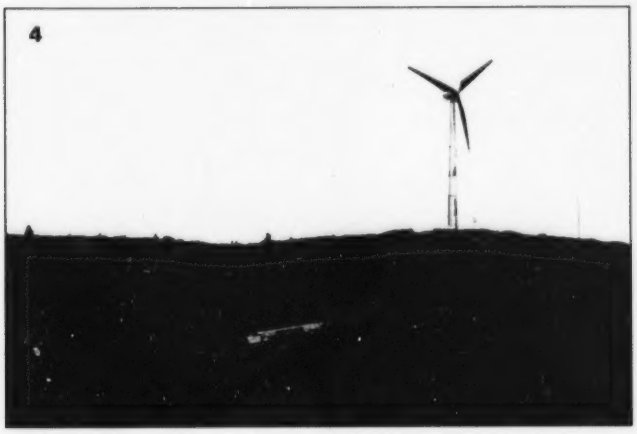
Specifications

- 660 kW capacity, 660 kW peak capacity
- 37-metre hub height (tubular tower)
- three-blade upwind design (fiberglass blades)
- 47-metre diameter blade circle
- power output pitch control regulated
- operates in wind speeds from 4 m/s (14 km/hr) to 25 m/s (90 km/hr)
- single speed (28.5 rpm), single generator (asynchronous)
- normal operating range to -30°C
- low-temperature steels and other cold climate modifications

The Vestas, with the Whitehorse sewage lagoons in the far distance.

Installing the Vestas



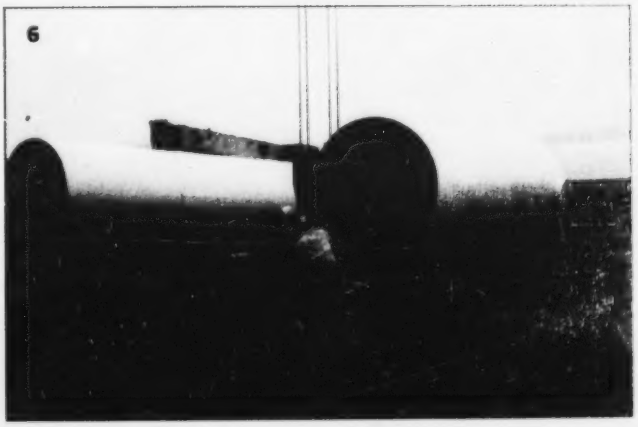


1) Widening the road up Haeckel Hill to accommodate the turbine towers, blades and crane. 2) Preparing the foundation. 3) Blades en route from Skagway, Alaska. 4) Crane snaking up Haeckel Hill. Note wind monitoring towers. 5-6) Preparing the tower pieces for installation.

"This Vestas tower was built in North Dakota. We had to bring up parts from all over the world — Denmark, the states and places like Mexico. Incidentally, it was a big stage. The road up Haeckel Hill was not adequate to take a turbine the size of the Vestas. And getting a 100-tonne crane up here was no easy matter.

"... needed low-temp packages for the turbine to be able to work in the middle of winter when our best winds are. We actually had to put custom modifications on the blades for blade heating and anemometers and wind vanes. We couldn't use the standard Vestas anemometers."

Bill Haydock, Supervisor, Mechanical Engineering, Yukon Energy Corporation



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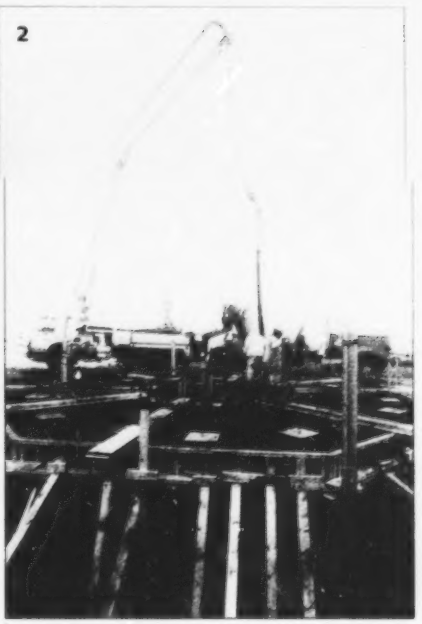

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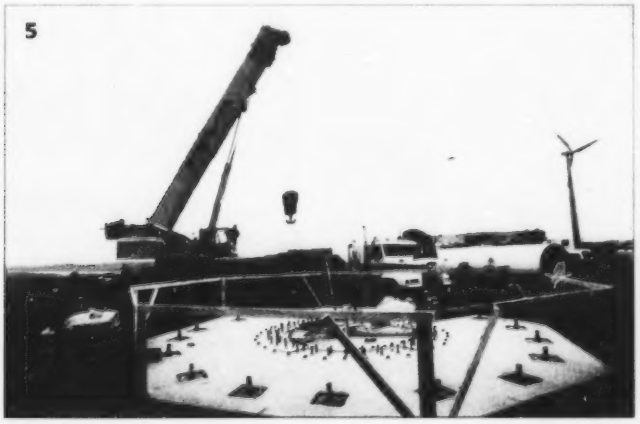

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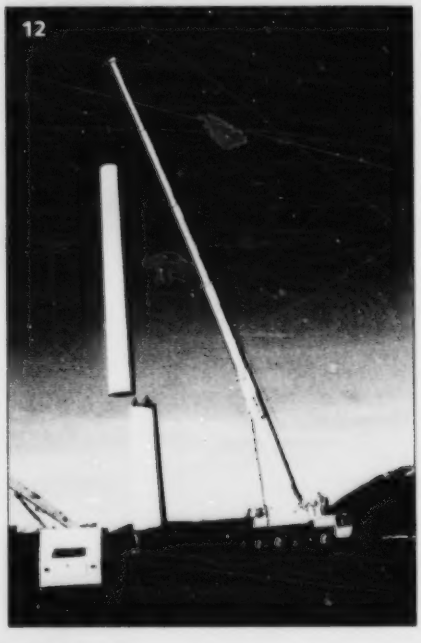

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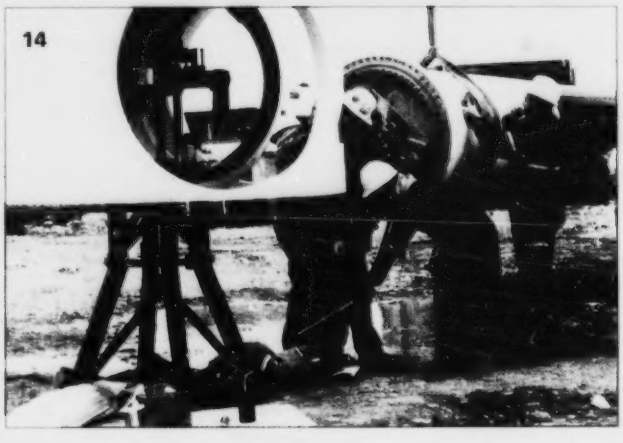


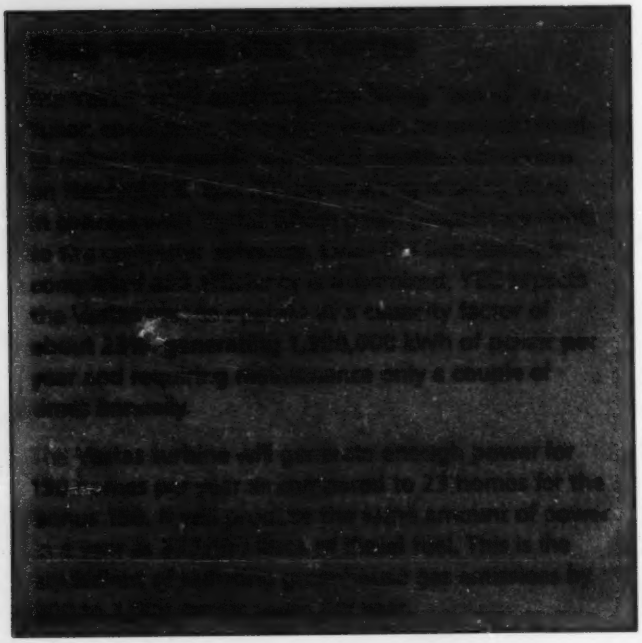
7) Hooking up the tower. 8) Setting the tower in place on its foundation. 9) Tightening one of the many bolts that holds the tower in place. 10) Looking up the ladder inside the tower. 11) Admiring the view from on high. 12) Lining up the second part of the tower. 13) Steadying the blade tip. 14) Joining a blade to the hub. 15-17) Finally, mounting the blade hub assembly to the nacelle. 18) Congratulations on a job well done!

Fine-tuning the Vestas

The Vestas wind turbine is now being "tuned" to Yukon conditions. Its computer will be programmed to reflect the specific wind and weather conditions on Haeckel Hill. This reprogramming is being done in concert with Vestas which holds proprietary rights to the computer software. Once the fine-tuning is completed and efficiency is maximized, YEC expects the Vestas unit to operate at a capacity factor of about 23%, generating 1,300,000 kWh of power per year and requiring maintenance only a couple of times annually.

The Vestas turbine will generate enough power for 130 homes per year as compared to 23 homes for the Bonus 150. It will produce the same amount of power in a year as 350,000 litres of diesel fuel. This is the equivalent of reducing greenhouse gas emissions by 900 to 1,000 metric tones per year.

7) Hooking up the tower. 8) Setting the tower in place on its foundation. 9) Tightening one of the many bolts that holds the tower in place. 10) Looking up the ladder inside the tower. 11) Admiring the view from on high. 12) Lining up the second part of the tower. 13) Steadying the blade tip. 14) Joining a blade to the hub. 15-17) Finally, mounting the blade/hub assembly to the nacelle. 18) Congratulations on a job well done!



CONTINUING COMMITMENT TO WIND

The Yukon government has put together a comprehensive energy plan to respond to the challenges of climate change. The goals of this plan are to displace diesel electrical production, reduce greenhouse gas emissions and increase the generation and sale of small-scale renewable energy, while continuing to meet the electrical service needs of Yukon communities and industry.

The components of this plan include the Green Power Initiative, the Wind Research and Development Initiative and the Energy Efficiency Initiative.

Wind research and development to date

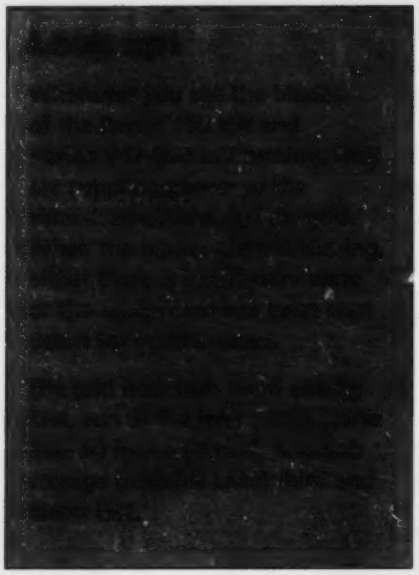
- Bonus 150 kW wind turbine to test technical viability of wind power generation.
- Vestas V47-660 kW to test commercial viability of wind power generation.
- Yukon Energy Corporation monitoring for commercially viable wind generation sites. Current sites include Mount Sumanik, Haeckel Hill and Destruction Bay.
- The Yukon government's Community Wind Resource Assessment program to support identification of community and individual wind generation options.

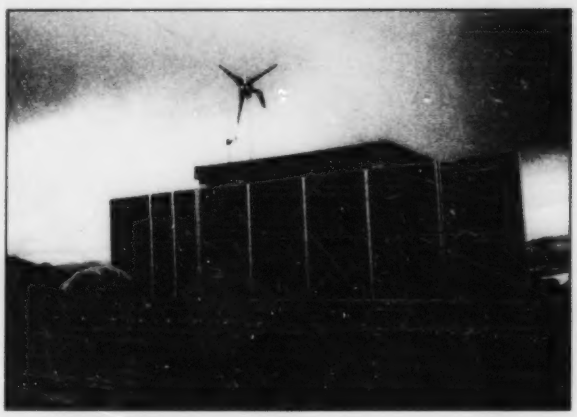
Community Wind Resource Assessment Program

This program provides incentives and technical assistance for Yukon individuals and communities. Equipment and support are available to test wind energy as an alternate power to diesel. The objectives of the program are to identify feasible sites for wind generation, encourage use of wind energy for residential and general service purposes, increase Yukon-based technical expertise in wind technology, and foster long-term, cost-competitiveness of renewable power for Yukon consumers.

Under this program, monitoring equipment is currently installed at five locations in the Yukon. Wind data will be analyzed and provided to program participants on an annual basis. The monitoring sites will be relocated yearly and the collected data will be used to develop a Yukon wind atlas.

Although there has been wind monitoring in the Yukon since 1982, the Bonus and Vestas wind turbines are just beginning to tap our wind energy potential. Continuing monitoring efforts are laying the foundation for future wind generation.





(left) Wind monitoring equipment on Mount Sumanik and (right) wind turbines on Haeckel Hill.

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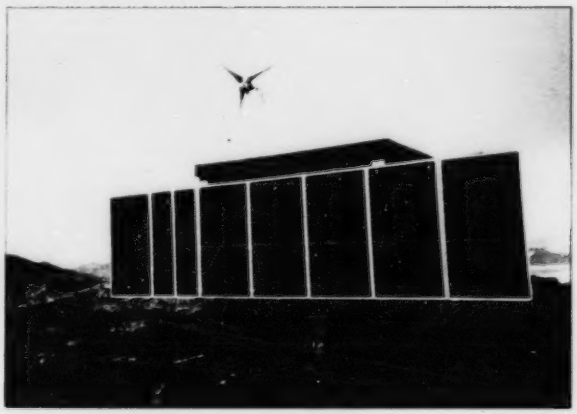
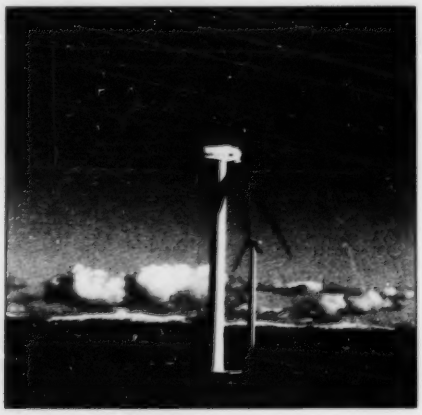
Look up!

Whenever you see the blades of the Bonus 150 kW and Vestas V47-660 kW turning, they are suppling power to the Whitehorse/Aishihik/Faro grid. When the blades are not turning, either there is insufficient wind or the equipment has been shut down for maintenance.

The grid now uses wind energy first, run of the river (Whitehorse Rapids) hydro second, reservoir storage (Aishihik Lake) third and diesel last.





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Photographs courtesy of the Government of the Yukon, Doug Craig, Jack Cable, Boreal Alternate Energy Centre, Yukon Energy Corporation and Yukon Development Corporation.

April, 2001